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WETTING OF SOLID SURFACES BY SOLUTIONS OF MODIFYING ADDITIVES

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The results of investigations of the effect of a complex additive containing sodium tripolyphosphate and resorcinol furfural oligomer on the wetting of solid surfaces are presented. It is shown that the wetting energy of an aluminum plate by solutions with a complex additive is much higher than the total energy of wetting by solutions containing separate components of a complex. The complex additive studied increases the wetting of an Al_2O_3 surface, which decreases the free surface energy at the solid – solution interface.

Key words: complex additive, suspension, wetting energy, ultimate dynamic stress, coagulation.

The production of modern construction articles is based on the preparation of high-quality initial material. One quality indicator for initial suspensions (ceramic slips and others) is their aggregative stability, i.e., conservation of the dispersity of the particles. Aggregative stability requires a stabilizer and good wetting of the surface of the particles of the disperse phase of the dispersion medium, since this allows an elastic solvation shell preventing particles from coagulating to form on the particle surfaces.

Different additives are used as stabilizers. Our investigations [1 – 5] as well as existing publications [6 – 8] show that for many complex mineral suspensions, which ceramic slips and clay suspensions are, it is more effective to use complex stabilizing additives containing several components. This makes it possible to expand the range of possibilities for purposeful control of the properties of mineral suspensions and the properties of articles based on them.

The angle of contact usually serves as a measure of wetting. The magnitude of this angle depends only on the nature of the substances participating in wetting, i.e., on the surface tension at the corresponding phase interfaces. One problematic question is the determination of wetting of powdered materials, for which the direct measurement of the contact angle presents significant difficulties. For this reason, model systems comprising the compounds SiO_2 and Al_2O_3 were chosen for the present investigations. These compounds as well as the products of their interaction form the bulk of the minerals and rocks which comprise the initial materials for ceramic materials and articles. The investigation of the properties of mineral suspensions based on the chosen compounds is of theoretical and practical interest.

We studied the wetting energy of solid surfaces wet by a solution containing a complex modifying additive making it possible to regulate the rheological properties of kaolin suspensions. The components of this additive are sodium tripolyphosphate (STPP) and resorcinol furfural oligomer SB-RF [3].

Investigations to determine the wetting energy on different surfaces showed that the wetting energy of Al_2O_3 plates wetted by solutions with a complex additive is much higher than the total wetting energy of an Al_2O_3 surface wetted by solutions of SB-RF and STPP separately (Fig. 1). That is to say, the phenomenon of synergism is observed: the action of separate components is intensified when they are introduced together.

Synergism can be due to the interaction of adsorbate molecules on the surfaces of particles as well as the formation of molecular components in solution.

To determine the possibility of the formation of such complexes we performed measurements of the electric conductance K of a solution with constant mass content of the complex additive SB-RF + STPP but different ratios of the components. The results of the investigation are presented in Fig. 2.

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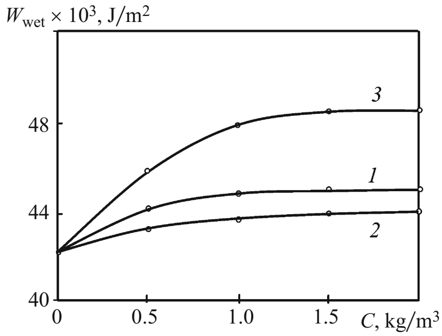

Fig. 1. Effect of the mass content C of additives on the wetting energy W_{wet} of an Al_2O_3 surface: *1*) SB-RF; *2*) STPP; *3*) complex composition.

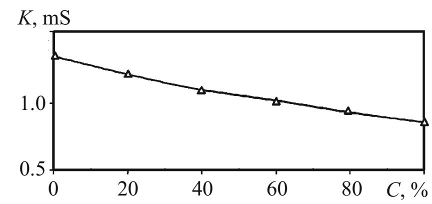

Fig. 2. Electric conductance K of a solution versus the content (by weight) of SB-RF in a complex additive.

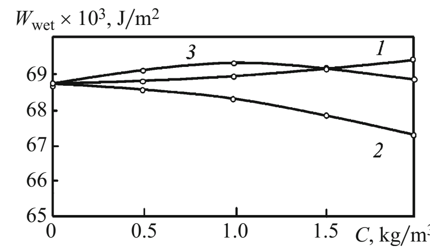

Fig. 3. Effect of additives on the wetting energy W_{wet} of a SiO_2 surface: *1*) SB-RF; *2*) STPP; *3*) complex composition.

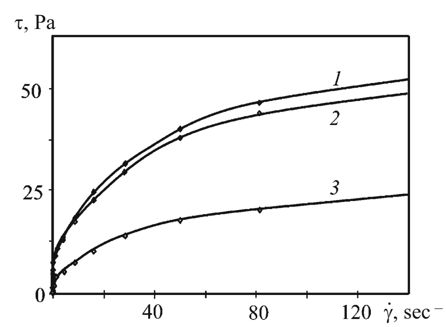

Fig. 4. Effect of additives on the rheological curves of alumina: τ) dynamic shear stress; $\dot{\gamma}$) gradient of the shear rate; *1*) SB-RF; *2*) STPP; *3*) complex composition.

In the case that molecular complexes are formed an inflection corresponding to the composition of the complex should be observed on the curve. It is evident from Fig. 2 that in the entire range of variation of the ratio of SB-RF and STPP a practically rectilinear relation is observed between the change in the ratio of the components and the electric conductance of the solution. This shows that the individual components of the additive do not form complexes in solution.

Therefore the intensification of the action of individual components when they are introduced together can be explained by the effect of the adsorbate molecules on one another on the surface of the particles.

The wetting energy of the quartz surface (Fig. 3) remains practically unchanged when using solutions of the complex additive as well as solutions of SB-RF and solutions of STPP separately. This can be explained by the fact that the surface of a quartz plate is more hydrophylic (contact angle $\theta = 13°$) than the surface of aluminum oxide ($\theta = 54°$). The introduction of an additive into the solutions can result in additional hydrophylization of the quartz surface, whose surface hydrophylicity is already high. Synergism is not observed when the components of the complex act separately on the wetting energy of quartz.

Since the value of the specific free surface energy on the solid – air boundary remained constant in the present investigations, the change in the wetting energy with the introduction of additives into the solution according to the equation

$$W_{wet} = \sigma_{sol-gas} - \sigma_{sol-liq},$$

where $\sigma_{sol-gas}$ and $\sigma_{sol-liq}$ are the specific free surface energy on the solid – gas interface and the solid – liquid interface, respectively, is due to the change in the specific free surface energy on the solid – solution boundary.

B. V. Deryagin, et al. [9] have shown that there is a relation between the strength P_1 of coagulation contact between the particles of the disperse phase and the surface tension at the disperse phase – dispersion medium interface. It was determined that the contact is weakened when liquid flows into the region between the particles of the disperse phase, which is accompanied by a reduction of the surface tension at the disperse phase – dispersion medium interface. The value of P_1 decreases by the amount of the wetting energy.

It is evident from Fig. 1 that when additives are introduced the wetting energy of an Al_2O_3 surface increases and therefore the specific surface energy at the solid – solution interface decreases. In addition complex additives have a large effect on the wetting energy.

The wetting of surfaces by a solution is directly related with the mobility of the suspensions. The rheological curves of suspensions of alumina and silica with complex and individual additives (0.1% in terms of dry matter) are presented in Figs. 4 and 5. It is evident from Figs. 1, 3 and 4, 5 that there is qualitative correspondence between the effect of additives on the wetting energy of an Al_2O_3 surface and on the maximum dynamic shear stress τ_o of a suspension containing Al_2O_3, characterizing the strength of the coagulation structure. Synergism is observed when the complex additive af-

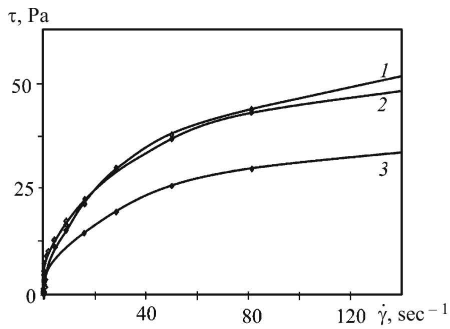

Fig. 5. Effect of additives on the rheological curves of silica: τ) dynamic shear stress; $\dot{\gamma}$) gradient of the shear rate; *1*) SB-RF; *2*) STPP; *3*) complex composition.

fects the maximum dynamic shear stress and the wetting energy of the Al_2O_3 surface.

Synergism is also observed in the effect of a complex additive on the rheological parameters of silica suspensions. However, since additives have virtually no effect on the wetting energy of the silica particles, this effect can be explained by the action of structure forces which increase the aggregative stability and mobility of suspensions.

In summary, the complex additive studied here increases the wetting of an Al_2O_3 surface, which promotes the formation of a solvation shell around particles and decreases the free surface energy at the solid – solution boundary. As a result, the tendency of particles toward coagulation decreases and, in consequence, the mobility of a suspension increases.

Since clayey minerals are formed largely by two structural elements — silicon-oxygen tetrahedra and aluminum-oxygen octahedral, the synergism observed in the study of the rheological parameters of clayey suspensions with a complex additive can also be explained by, aside from the action of other factors, the larger reduction in the strength of coagulation contacts between particles due to the presence of aluminum compounds, a result of which is an increase in the aggregative stability of the suspension.

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